CRUST AND MANTLE STRUCTURE OF LARGE CORONAE ON VENUS. Laurel Senft, *Department of Earth and Atmospheric Sciences, Cornell University, Ithaca NY 14853,* Walter S. Kiefer, *Lunar and Planetary Institute, Houston TX 77058, (kiefer@lpi.usra.edu, http://www.lpi.usra.edu/science/kiefer/home.html).*

Coronae are circular to elliptical tectonic structures on Venus, typically a few hundred kilometers across and often associated with volcanic activity. They are generally believed to be the surface expression of upwelling mantle diapirs [e.g., 1]. Gravity modeling can provide insight into the subsurface structure of coronae. Previous gravity models of coronae have emphasized determining parameters such as the average crustal and lithospheric thicknesses [2,3]. In this work, we analyze the spatial variability of crustal thickness and mantle densities at the two largest coronae, Artemis and Heng-O, as well at large coronae in Central and Eastern Eistla and near Diana and Dali Chasma.

Model

We apply a two-layer inversion model, which has been used previously in a study of the Hecate, Parga, and Themis coronae chains [4] and more recently in a study of Phoebe Regio and Devana Chasma [5]. This model uses gravity and topography to constrain the density anomalies in two shells at two different depths in the planet. In this model, the shallow shell is assumed to represent variations in crustal thickness, supported by a combination of Airy isostasy and elastic flexure. The deeper shell is assumed to represent density anomalies in the mantle of Venus, which drive whole-mantle convective flow. Density anomalies in the mantle are interpreted in terms of lateral variations in temperature. As a first approximation, we assume that the density anomalies are vertically continuous from 100 km depth (the base of the upper thermal boundary layer) to 700 km depth; the results should therefore be interpreted as a vertically averaged upper mantle structure.

We invert spherical harmonic representations of the gravity and topography of Venus [6,7] for spherical harmonic degrees 2-40. Because short wavelengths suffer from rapid vertical attenuation, this choice of cut-off wavelength is a compromise between horizontal resolution and sensitivity to upper mantle structure. The models have a half-wavelength spectral resolution of 475 km. In practice, a diapir of a given diameter will have power over a range of spectral wavelengths, including some power at wavelengths longer than the resulting corona diameter. Thus, we should be able to detect diapirs that are somewhat smaller than 475 km in diameter. However, because of the resolution of the models, the thermal anomalies mapped here will generally be less than the total amplitude of the anomalies.

Results

Artemis Corona: Artemis is the largest corona on Venus (2600 km diameter). It has alternately been proposed to be the surface expression of a hot mantle plume [8] or to have subduction or underthrusting on its periphery [9,10]. Our results show that the region has a warm mantle (maximum temperature anomaly 106 K, RMS temperature anomaly 50 K). Temperature maxima generally occur near the periphery of the corona, including the Quilla Chasma rift system and the volcanic shield field [8] in eastern Artemis. There is no evidence in our results for subduction beneath Artemis. The cold mantle in Figure 1a is restricted to the Nsomeka Planitia plains, 1500 km south of the Artemis rim. Despite the warm mantle temperatures, there has been relatively little volcanism, as shown by the crustal thickness anomaly map (Figure 1b). The exceptions are near 116 E, 30 S (corona C10 of [8]), where the crust is 5.8 km thicker than the global average, and near 134 E, 27 S, where the crust is 6.9 km thinner than the global average. 76% of the long-wavelength topography is dynamically supported by the mantle flow.

Diana and Dali Chasma: The Diana Chasma rift system has only a weak thermal anomaly. In contrast, the Dali Chasma region of coronae and rifts has a pervasively warm mantle (RMS temperature anomaly 53 K). Temperature maxima along Dali are 94 K on the north rim of Atahensik Corona and 87 K southeast of Zemina Corona. (Atahensik Corona was referred to informally as "Latona" in some earlier literature.) These results indicate that Dali Chasma remains geologically active. Subduction was proposed to produce the trenches along the southern margin of Atahensik and near Miralaidji Corona [9] and was disputed on the basis of geologic mapping [11]. There is no evidence for cold material in our mantle temperature map. 83% of the long-wavelength topography near Dali Chasma is dynamically supported by the mantle flow. The crustal thickness map indicates that volcanism has not been particularly important in most of this region. The maximum crustal thickening is 3.4 km in southwestern Atahensik Corona.

Central Eistla Regio: The two major structures in this region, Anala Mons and Irnini Mons (also known as Sappho Patera) are intermediate in form between shield volcanos and coronae [12]. The hot mantle thermal anomaly in this region encompasses both Anala and Irnini. The temperature maximum of 74 K is centered at Anala. The temperature anomaly beneath Irnini is 50-60 K. Superposition relationships between lava flows indicate that Anala is the younger of the two volcanos [13], but our results suggest that both probably are still active. At Nehalennia Corona, the temperature anomaly is 30 K. The maximum crustal thickness anomaly is 3.5 km at Irnini Mons. The difference in spatial location between the maximum thermal anomaly and maximum crustal thickening is close to the limit of the gravity inversion's resolution and may not be statistically meaningful. If the difference is real, it indicates that the time-integrated volume of volcanic activity was greater at Irnini than at Anala. Geologic mapping indicates that significant uplift occurred after the regional plains were emplaced, but can not quantify the overall relative importance of uplift and volcanic construction in supporting the regional topography [12]. Our results indicate that 72% of the long-wavelength topography in Central Eistla is dynamically supported by mantle uplift. Of the two models presented by McGill to explain the unusual structure of Anala and Irnini

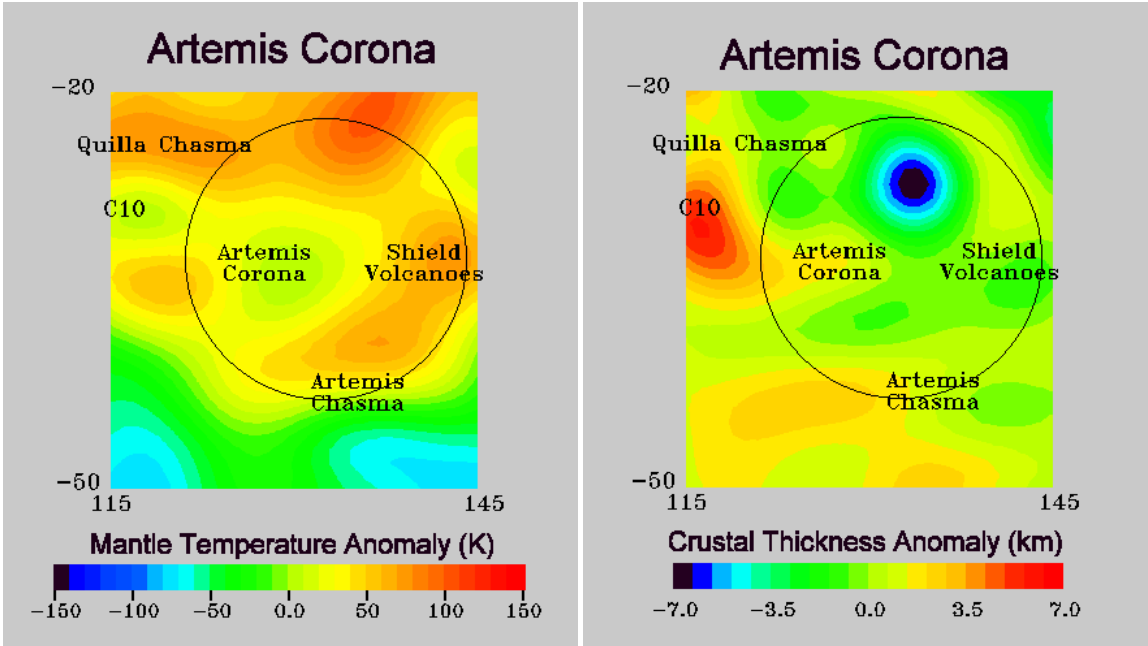

Figure 1: Left: Mantle temperature anomalies (departures from the average mantle temperature) at Artemis Corona. Right: Crustal thickness anomalies at Artemis. The circle outlines the rim of Artemis Corona.

[12], it appears that the uplift model is the most likely.

Eastern Eistla Regio: There are five large coronae in Eastern Eistla Regio [3]. Mantle temperature highs occur as two linear structures, oriented approximately north-south and closely associated with four of the coronae. The temperature maxima for the western coronae pair, Didilia and Pavlova, and for the eastern pair, Isong and an unnamed structure at 48 E, 17 N, are both 61 K. Calakomana, geologically the oldest corona in Eastern Eistla [3], is just east of the western high temperature structure. The maximum crustal thickening is at Pavlova (5.2 km) and at the unnamed corona (4.1 km). At Calakomana, the crust is actually 3.3 km thinner than the global average. 52% of the long-wavelength topography in Eastern Eistla is dynamically supported by the mantle flow.

Heng-O: Heng-O is the second largest corona on Venus (965 km diameter) and has a prolonged geologic history [14]. Warm mantle occurs under the southern two-thirds of the corona floor, roughly corresponding to the volcanic units hv1, hv2, and hv3 of [14]. The temperature maximum, 56 K at 354 E, 1 N, occurs in the intermediate age volcanic unit hv2. These observations suggest that Heng-O may remain active at present. The crustal thickness map indicates that little volcanic thickening of the crust has occurred in this region.

Implications

These results indicate that hot thermal anomalies currently exist at many large coronae on Venus. This supports the diapir model for corona formation. Our results disagree with proposals that subduction occurs on the margin of coronae, which would place cold mantle material both on the outer margin of the corona and as well as beneath the interior of the corona. Based on a consideration of both advective and conductive cooling timescales, Kiefer and Peterson [5] showed that large positive thermal anomalies would disappear in less than 150 million years unless the anomalies were actively maintained by mantle convection. Thus, our results indicate that many of the coronae in our study regions have been active in the recent past. On the other hand, a similar gravity study of the Phoebe Regio region showed that Aruru Corona and the shield volcano Tuulikki Mons are both now geologically dead [5].

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